Kongeriget Danmark

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

Patent application No.:	PA 2002 01400
Date of filing:	23 September 2002
Applicant: (Name and address)	Telefonaktiebolaget L M Ericsson (publ) SE-126 25 Stockholm Sweden

Title: Method and device for detection of a signal

IPC: H 04 B 1/707; H 04 J 13/02// H 04 Q 7/38

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EP 03/9657

Patent- og Varemærkestyrelsen
Økonomi- og Erhvervsministeriet

5 September 2003

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Method and device for detection of a signal.

The detection of the Acquisition Indicator Channel (AICH) is part of the random access procedure. The procedure can be described as follows. In order for the terminal to send a Random Access Channel (RACH) message, it first needs to decode the Broadcast Channel (BCH) to find out what are the available RACH sub-channels, scrambling codes, and signatures. The terminal selects randomly one of the RACH sub-channels from the group its access class allows it to use. This puts restriction on when we can send a RACH preamble. Then the signature is selected randomly, there are sixteen signatures available, which means that sixteen user equipments (UE) can send at the same time. The downlink power level is then measured and the uplink power level is set with proper margin due to the open loop inaccuracy. A 1 ms RACH preamble is sent with the selected signature. The UE then listens for a confirmation from the base-station. The confirmation is sent through the AICH. In case no AICH is detected, the terminal increases the preamble transmission power by a step given by the base station. The preamble is then retransmitted in the next available access slot. When finally an AICH transmission from the base-station is detected in the UE, the terminal transmits the 10 ms or 20 ms message part of the RACH transmission.

A 'RAKE'/a RAKE receiver is typically used in digital wireless communication systems to improve the performance of a CDMA receiver by utilizing signal energy carried by many multipath components. In a RAKE receiver this is achieved by letting each multipath component being assigning a despreader whose reference copy of the spreading code is delayed equally to the path delay of the corresponding multipath component. The outputs of the despreaders (fingers) are then coherently combined to produce a symbol estimate. The RAKE receiver uses knowledge of the multipath delays and the values of the channel impulse response for all paths.

Presently, no specific and complete solution for AICH detection is known. Especially the thresholding has not been thoroughly examined/disclosed.

An object of the present invention is to provide a complete method of and a device usable for AICH detection and detection of other types of signals.

A further object of the present invention is to provide a detection method and detection device that enables detection of an acquisition signal even when the physical detector is moved at a relatively large velocity.

An additional object of the present invention is to provide a detection method/device having a more robust detection.

A further object of the present invention is to provide a threshold for detection vs. no detection of an acquisition signal.

The objects, among others, are achieved by a method (and corresponding device) of detecting an acquisition signal, comprising the steps of:

- receiving a first signal comprising an access slot comprising a first slot part and a second slot part, each slot part comprising a number of signal symbols,
- obtaining a signature pattern comprising a first signature part and a second signature part, each signature part comprising a number of signature symbols,
- multiplying each signal symbol of said first slot with corresponding signature symbols of said first signature part and deriving a first sum of the products of multiplication,
- multiplying each signal symbol of said second slot with corresponding signature symbols of said second signature part and deriving a second sum of the products of multiplication,
- obtaining a first and a second weight factor, and
- adding said first sum multiplied by said first weight factor and said second sum multiplied by said second weight factor giving a first result, and
- comparing said first result and a detection threshold in order to determine whether an acquisition signal is detected or not.

In one embodiment, said detection threshold is derived based on a signal to interference ratio of a common pilot channel (CPICH).

In one embodiment, said method further comprises a step of deriving said detection threshold.

In one embodiment, said first and second weight factors are derived on the basis of a signal to interference ratio (SIR) calculated for a common pilot channel (CPICH).

In one embodiment, said first signal is selected from the group of:

- an AICH signal, and
- another type of signal.

In one embodiment, said first signal is an estimated signal derived on the basis of weighted channel estimates, based on a common pilot channel (CPICH), and of de-spread symbols from a RAKE.

A weighted channel estimate (w) may e.g. be given by

$$w = \frac{\overline{h}}{I} \qquad w = \overline{h}$$

where $\overline{h}$ and I is explained later.

The invention also relates to a method of detection an acquisition signal, where said method comprises accumulation of received signature symbols in groups/blocks, the groups/blocks being weighted before being summed, deriving a indication threshold used for determining an acquisition indicator, said threshold being dependent on a signal to interference ratio of a common pilot channel (CPICH).

The invention also relates to a device for detecting an acquisition signal, said device comprising:

- means for receiving a first signal comprising an access slot comprising a first slot part and a second slot part, each slot part comprising a number of signal symbols,

- *means for obtaining a signature pattern comprising a first signature* part and a second signature part, each signature part comprising a number of signature symbols,
- means for multiplying each signal symbol of said first slot with corresponding signature symbols of said first signature part and deriving a first sum of the products of multiplication,
- means for multiplying each signal symbol of said second slot with corresponding signature symbols of said second signature part and deriving a second sum of the products of multiplication,
- means for obtaining a first and a second weight factor, and
- means for adding said first sum multiplied by said first weight factor and said second sum multiplied by said second weight factor giving a first result, and
- means for comparing said first result and a detection threshold in order to determine whether an acquisition signal is detected or not.

The invention also relates to a device for detection an acquisition signal, said device comprising means for accumulation of received signature symbols in groups/blocks, means for weighting the groups/blocks before being summed, means for deriving a indication threshold used for determining an acquisition indicator, said threshold being dependent on a signal to interference ratio of a common pilot channel (CPICH).

Further embodiments of a device according to the present invention corresponds to the embodiments of a method according to the present invention.

The AICH detection is essentially a correlation. Judging from the size of the correlation output we determine if we have detected an AICH or not. This requires a threshold to distinguish detection from no detection, which is part of the present invention.

The present invention splits a received signal up into parts and assigns a weight factor to each part and sums the weighted parts and uses a threshold in order to determine whether a given (acquisition) signal is present/detected or not.

One prior art method/device of/for signal detection simply uses a summation of parts, which is less robust and does not provide reliable detection when a detector moves at a relatively high speed/velocity.

The invention could advantageously be part of a baseband chip in future UMTS terminals. Generally, the invention may be useful in all markets relating to/involving UMTS terminals.

Although, AICH detection is used throughout the specification, the invention may also be used in detecting other kinds/types of signals.

Figure 1 illustrates a schematic block diagram of a device according to the present invention.

Figure 2 illustrates a number of signature patterns.

References:

[1] 3GPP, *3rd generation partnership project specifications*, 3GPP TS 25.133, V3.3.0, June 2001. (incorporated herein by reference)

[2] 3GPP, *3rd generation partnership project specifications*, 3GPP TS 25.101, V3.4.0, June 2001. (incorporated herein by reference)

[3] E. Jonsson, *Windowing in the combiner input and output*, ECS/GTU/D-01:5056 (incorporated herein by reference)

[4] J. Proakis, *Digital communications*, McGraw-Hill Int. Edition, 3rd Ed, 1995 (incorporated herein by reference)

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ACLR Adjacent Channel Leakage power Ratio
ACS Adjacent Channel Selectivity
AICH Acquisition Indication Channel
BER Bit Error Ratio
BLER Block Error Ratio
CQI Channel Quality Indicator
CW Continuous Wave (un-modulated signal)
DCH Dedicated Channel, which is mapped into Dedicated Physical Channel.
DL Down Link (forward link)
DTX Discontinuous Transmission
DPCCH Dedicated Physical Control Channel
DPCH Dedicated Physical Channel
$DPCH\_E_c$ Average energy per PN chip for DPCH.
$\frac{DPCH\_E_c}{I_{or}}$ The ratio of the transmit energy per PN chip of the DPCH to the total transmit power spectral density at the Node B antenna connector.
DPDCH Dedicated Physical Data Channel
EIRP Effective Isotropic Radiated Power
E_c Average energy per PN chip.
$\frac{E_c}{I_{or}}$ The ratio of the average transmit energy per PN chip for different fields or physical channels to the total transmit power spectral density.
FACH Forward Access Channel
FDD Frequency Division Duplex
FDR False transmit format Detection Ratio. A false Transport Format detection occurs when the receiver detects a different TF to that which was transmitted, and the decoded transport block(s) for this incorrect TF passes the CRC check(s).
F_{uw} Frequency of unwanted signal. This is specified in bracket in terms of an absolute frequency(s) or a frequency offset from the assigned channel frequency.
HSDPA High Speed Downlink Packet Access
HS-DSCH High Speed Downlink Shared Channel
HS-PDSCH High Speed Physical Downlink Shared Channel
HARQ Hybrid ARQ sequence
Information Data Rate
Rate of the user information, which must be transmitted over the Air Interface. For example, output rate of the voice codec.
I_o The total received power spectral density, including signal and interference, as measured at the UE antenna connector.

I_{oc}	The power spectral density (integrated in a noise bandwidth equal to the chip rate and normalized to the chip rate) of a band limited white noise source (simulating interference from cells, which are not defined in a test procedure) as measured at the UE antenna connector.
I_{or}	The total transmit power spectral density (integrated in a bandwidth of (1+α) times the chip rate and normalized to the chip rate)of the downlink signal at the Node B antenna connector.
$\hat{I}_{or}$	The received power spectral density (integrated in a bandwidth of (1+α) times the chip rate and normalized to the chip rate) of the downlink signal as measured at the UE antenna connector.
MER	Message Error Ratio
Node B	A logical node responsible for radio transmission / reception in one or more cells to/from the User Equipment. Terminates the Iub interface towards the RNC
OCNS	Orthogonal Channel Noise Simulator, a mechanism used to simulate the users or control signals on the other orthogonal channels of a downlink link.
$OCNS\_E_c$	Average energy per PN chip for the OCNS.
$\frac{OCNS\_E_c}{I_{or}}$	The ratio of the average transmit energy per PN chip for the OCNS to the total transmit power spectral density.
P-CCPCH	Primary Common Control Physical Channel
PCH	Paging Channel
$P\text{-}CCPCH\ \frac{E_c}{I_o}$	The ratio of the received P-CCPCH energy per chip to the total received power spectral density at the UE antenna connector.
$\frac{P\text{-}CCPCH\_E_c}{I_{or}}$	The ratio of the average transmit energy per PN chip for the P-CCPCH to the total transmit power spectral density.
P-CPICH	Primary Common Pilot Channel
PICH	Paging Indicator Channel
PPM	Parts Per Million
R	Number of information bits per second excluding CRC bits successfully received on HS-DSCH by a HSDPA capable UE.
<REFSENS>	Reference sensitivity
<REF $\hat{I}_{or}$>	Reference $\hat{I}_{or}$
RACH	Random Access Channel
SCH	Synchronization Channel consisting of Primary and Secondary synchronization channels
$S\text{-}CCPCH$	Secondary Common Control Physical Channel.
$S\text{-}CCPCH\_E_c$	Average energy per PN chip for S-CCPCH.
SIR	Signal to Interference ratio
SSDT	Site Selection Diversity Transmission
STTD	Space Time Transmit Diversity
TDD	Time Division Duplexing
TFC	Transport Format Combination
TFCI	Transport Format Combination Indicator
TPC	Transmit Power Control
TSTD	Time Switched Transmit Diversity
UE	User Equipment
UL	Up Link (reverse link)
UTRA	UMTS Terrestrial Radio Access

6.5 Transmit ON/OFF power

6.5.1 Transmit OFF power

Transmit OFF power is defined as the average power when the transmitter is off. The transmit OFF power state is when the UE does not transmit except during UL compressed mode.

6.5.1.1 Minimum requirement

The transmit OFF power is defined as the RRC filtered mean power in a duration of at least one timeslot excluding any transient periods. The requirement for the transmit OFF power shall be less than –56 dBm.

6.5.2 Transmit ON/OFF Time mask

The time mask for transmit ON/OFF defines the ramping time allowed for the UE between transmit OFF power and transmit ON power. Possible ON/OFF scenarios are RACH ,CPCH or UL compressed mode.

6.5.2.1 Minimum requirement

The transmit power levels versus time shall meet the mask specified in figure 6.2 for PRACH preambles and CPCH preambles, and the mask in figure 6.3 for all other cases. The off signal is defined as the RRC filtered mean power. The on signal is defined as the mean power.

The specification depends on each possible case.

- First preamble of RACH/CPCH: Open loop accuracy (Table 6.3).
- During preamble ramping of the RACH/CPCH, and between final RACH/CPCH preamble and RACH/CPCH message part: Accuracy depending on size of the required power difference.(Table 6.7). The step in total transmitted power between final RACH/CPCH preamble and RACH/CPCH message (control part + data part) shall be rounded to the closest integer dB value. A power step exactly half-way between two integer values shall be rounded to the closest integer of greater magnitude.
- After transmission gaps in compressed mode: Accuracy as in Table 6.9.
- Power step to Maximum Power: Maximum power accuracy (Table 6.1).

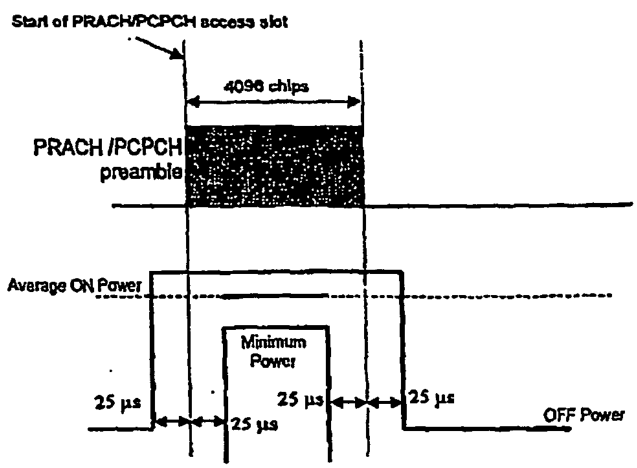

Figure 6.2: Transmit ON/OFF template for PRACH preambles and CPCH preambles

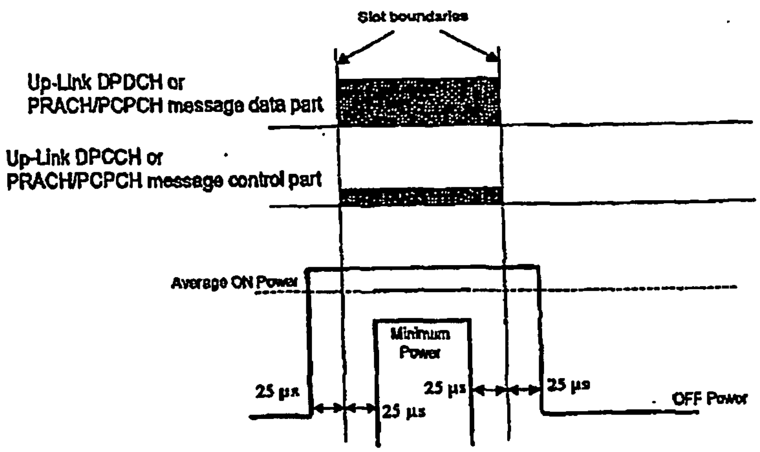

Figure 6.3: Transmit ON/OFF template for all other On/Off cases

Table 6.7: Transmitter power difference tolerance for RACH/CPCH preamble ramping, and between final RACH/CPCH preamble and RACH/CPCH message part

Power step size (Up or down)* ΔP [dB]	Transmitter power difference tolerance [dB]
0	+/- 1
1	+/- 1
2	+/- 1.5
3	+/- 2
4 ≤ ΔP ≤10	+/- 2.5
11 ≤ ΔP ≤15	+/- 3.5
16 ≤ ΔP ≤20	+/- 4.5
21 ≤ ΔP	+/- 6.5

NOTE: Power step size for RACH/CPCH preamble ramping is from 1 to 8 dB with 1 dB steps.

6.5.3 Change of TFC

A change of TFC (Transport Format Combination) in uplink means that the power in the uplink varies according to the change in data rate. DTX, where the DPDCH is turned off, is a special case of variable data, which is used to minimise the interference between UE(s) by reducing the UE transmit power when voice, user or control information is not present.

6.5.3.1 Minimum requirement

A change of output power is required when the TFC, and thereby the data rate, is changed. The ratio of the amplitude between the DPDCH codes and the DPCCH code will vary. The power step due to a change in TFC shall be calculated in the UE so that the power transmitted on the DPCCH shall follow the inner loop power control. The step in total transmitted power (DPCCH + DPDCH) shall then be rounded to the closest integer dB value. A power step exactly half-way between two integer values shall be rounded to the closest integer of greater magnitude. The accuracy of the power step, given the step size, is specified in Table 6.8. The power change due to a change in TFC is defined as the relative power difference between the mean power of the original (reference) timeslot and the mean power of the target timeslot, not including the transient duration. The transient duration is from 25µs before the slot boundary to 25µs after the slot boundary.

Table 8.38: The Requirements for DCH reception in Blind transport format detection

Test Number	$\frac{DPCH\_E_c}{I_{or}}$	BLER	FDR
1	-17.7 dB	10^{-2}	10^{-4}
2	-17.8 dB	10^{-2}	10^{-4}
3	-18.4 dB	10^{-2}	10^{-4}
4	-13.0 dB	10^{-2}	10^{-4}
5	-13.2 dB	10^{-2}	10^{-4}
6	-13.8 dB	10^{-2}	10^{-4}

* The value of DPCH_Ec/Ior, Ioc, and Ior/Ioc are defined in case of DPCH is transmitted

NOTE: In this test, 9 different Transport Format Combinations (Table 8.39) are sent during the call set up procedure, so that the UE has to detect the correct transport format from these 9 candidates.

Table 8.39: Transport format combinations informed during the call set up procedure in the test

	1	2	3	4	5	6	7	8	9
DTCH	12.2k	10.2k	7.95k	7.4k	6.7k	5.9k	5.15k	4.75k	1.95k
DCCH					2.4k				

8.11 Detection of Broadcast channel (BCH)

The receiver characteristics of Broadcast Channel (BCH) are determined by the Block Error Ratio (BLER) values. BCH is mapped into the primary common control physical channel (P-CCPCH).

8.11.1 Minimum requirement

For the parameters specified in Table 8.40 the average downlink power P-CCPCH_Ec/Ior shall be below the specified value for the BLER shown in Table 8.41.

This requirement doesn't need to be tested.

Table 8.40: Parameters for BCH detection

Parameter	Unit	Test 1	Test 2
Phase reference	-	P-CPICH	
I_{oc}	dBm/3.84 MHz	-60	
$\hat{I}_{or}/I_{oc}$	dB	-1	-3
Propagation condition		Static	Case 3

Table 8.41: Test requirements for BCH detection

Test Number	P-CCPCH_Ec/Ior	BLER
1	-18.5 dB	0.01
2	-12.8 dB	0.01

8.12 Demodulation of Paging Channel (PCH)

The receiver characteristics of paging channel are determined by the probability of missed paging message (Pm-p). PCH is mapped into the S-CCPCH and it is associated with the transmission of Paging Indicators (PI) to support efficient sleep-mode procedures.

8.12.1 Minimum requirement

For the parameters specified in Table 8.42 the average probability of missed paging (Pm-p) shall be below the specified value in Table 8.43. Power of downlink channels other than S-CCPCH and PICH are as defined in Table C.3 of Annex C. S-CCPCH structure is as defined in Annex A.6.

Table 8.42: Parameters for PCH detection

Parameter	Unit	Test 1	Test 2
Number of paging indicators per frame (Np)	-	72	
Phase reference	-	P-CPICH	
I_{oc}	dBm/3.84 MHz	-60	
$\hat{I}_{or}/I_{oc}$	dB	-1	-3
Propagation condition		Static	Case 3

Table 8.43: Test requirements for PCH detection

Test Number	S-CCPCH_Ec/Ior	PICH_Ec/Ior	Pm-p
1	-14.8	-19.2	0.01
2	-9.8	-12.2	0.01

8.13 Detection of Acquisition Indicator (AI)

The receiver characteristics of Acquisition Indicator (AI) are determined by the probability of false alarm Pfa and probability of correct detection Pd. Pfa is defined as a conditional probability of detection of AI signature given that a AI signature was not transmitted. Pd is defined as a conditional probability of correct detection of AI signature given that the AI signature is transmitted.

8.13.1 Minimum requirement

For the parameters specified in Table8.44 the Pfa and 1-Pd shall not the exceed the specified values in Table 8.45. Power of downlink channels other than AICH is as defined in Table C.3 of Annex C.

Table 8.44: Parameters for AI detection

Parameter	Unit	Test 1
Phase reference	-	P-CPICH
I_{oc}	dBm/3.84 MHz	-60
Number of other transmitted AI signatures on AICH	-	0
$\hat{I}_{or}/I_{oc}$	dB	-1
AICH_Ec/Ior	dB	-22.0
AICH Power Offset	dB	-12.0
Propagation condition	-	Static

Note that AICH_Ec/Ior can not be set. Its value is calculated from other parameters and it is given for information only. (AICH_Ec/Ior = AICH Power Offset + CPICH_Ec/Ior)

Table 8.45: Test requirements for AI detection

Test Number	Pfa	1-Pd
1	0.01	0.01

8.14 Detection of Access Preamble Acquisition Indicator Channel (AP-AICH)

The requirement for detection of the AP-AICH for CPCH is the same as the requirement for detection of the AI which is described in section 8.13 of this specification.

8.15 Detection of Collision Detection/Channel Assignment Indicator Channel (CD/CA-ICH)

The requirement for detection of the CD/CA-ICH for CPCH is the same as the requirement for detection of the AI which is described in section 8.13 of this specification.

8.16 Demodulation of CPCH Status Indicator Channel (CSICH)

The receive characteristics of the CPCH Status Indicator Channel (CSICH) are determined by the average message error Ratio (MER). Under the test conditions described below, a CSICH message demodulation error will cause the UE to transmit a CPCH message when there is pending UL data to transmit. MER is measured at the message rate listed for the conditions in Table 8.46.

8.16.1 Minimum requirement

For the parameters and conditions specified in Tables 8.46, 8.47 and 8.48 the MER shall not exceed the values listed in table 8.49.

Other downlink channels which are present in this test are P-CPICH, P-CCPCH, and PICH, and their powers are as specified in Annex C.3.2.

Table 8.46: CPCH test parameters and conditions for CSICH performance

Parameter	Test 1	Test 2
CPCH mode	UE Channel Selection (PCPCH availability is broadcast in CSICH)	
Number of PCPCHs in CPCH set	15	
Number of SIs per CSICH frame	15 (one SI message per PCPCH)	
Number of CSICH bits per SI message	8 (CSICH bit repeated 8 times in each SI message)	
CSICH Message Rate	750 per second (15 messages in 20 msec frame)	
AP preamble signatures	15 PCPCHs are given 1 signature each; 1 signature is unused.	
AP preamble slot subchannels	All slot subchannels are available for access without delay.	
CD preamble signatures	16 (all signatures used)	
CD preamble slot subchannels	All slot subchannels are available for access without delay	
Persistency value for all PCPCHs	1 (full access, no delay)	
CSICH broadcast	N=15 SIs. For each PCPCH SI, SI=0 (PCPCH not available)	
AP-AICH broadcast	In each access slot, Node B transmits 15 AP-AICH-ACKs, one for each PCPCH.	
Channel Assignment (CA)	Not active	
CD/CA-ICH broadcast	In each access slot, Node B transmits 16 CD/CA-ICH ACKs, one for each possible signature	
Power control preamble length for all PCPCHs	0 slots	
Message length for all PCPCHs	10 ms (1 TTI) (Nfmax = 1)	
Spreading factor for all PCPCHs	64	
Propagation condition	Static	Case 3

Table 8.47: AP-AICH test parameters for CSICH performance

Parameter	Unit	Test 1	Test 2
Phase reference	-	P-CPICH	
I_{oc}	dBm/3.84 MHz	-60	
Number of transmitted AI signatures on AP-AICH	-	15 (all ACK)	
$\hat{I}_{or}/I_{oc}$	dB	-1	-3
AP-AICH_Ec/Ior	dB	-10.0	
AP-AICH Power Offset	dB	0	
Propagation condition		Static	Case 3

Note that AP-AICH_Ec/Ior cannot be set. Its value is calculated from other parameters and it is given for information only. (AP-AICH_Ec/Ior = AP-AICH Power Offset + CPICH_Ec/Ior)

Table 8.48: CD/CA-ICH test parameters for CSICH performance

Parameter	Unit	Test 1	Test 2
Phase reference	-	P-CPICH	
I_{oc}	dBm/3.84 MHz	-60	
Number of transmitted CD signatures on CD/CA-ICH	-	16 (all ACK)	
$\hat{I}_{or}/I_{oc}$	dB	-1	-3
CD/CA-ICH_Ec/Ior	dB	-10.0	
CD/CA-ICH Power Offset	dB	0	
Propagation condition		Static	Case 3

Note that CD/CA-ICH_Ec/Ior cannot be set. Its value is calculated from other parameters and it is given for information only. (CD/CA-ICH_Ec/Ior = CD/CA-ICH Power Offset + CPICH_Ec/Ior)

Table 8.49: CSICH demodulation requirements

Test Number	CSICH power offset	CSICH MER
1	-10.5 db	0.001
2	-3.0 db	0.001

9 Performance requirement (HSDPA)

9.1 General

The performance requirements for the UE in this subclause apply for the reference measurement channels specified in Annex A.7, the propagation conditions specified in table B.1B of Annex B and the Down link Physical channels specified in Annex C.5.

9.2 Demodulation of HS-DSCH (fixed reference channel)

9.2.1 Single Link performance

The receiver single link performance of the High Speed Physical Downlink Shared Channel (HS-DSCH) in different multi-path fading environments are determined by the information bit throughput R

Algorithm and Implementation Description of the AICH Reception

Abstract

In this report a general algorithm for Acquisition Indicator Channel (AICH) detection is described and its implementation in the hardware. Performance simulations are presented as well as the necessary bit-widths for the hardware implementation.

1 Introduction

The Acquisition Indicator Channel (AICH) is sent using a spreading factor of 256. A total of 16 symbols are sent during an access slot, which translates to 10 symbols in one slot and 6 symbols in the next slot. The duration of an access slot equals two slots. The real and imaginary part of the sent symbols are equal. Up to 16 different symbol combinations can be sent. The different symbol combinations are orthogonal and are called signature patterns, see [1]. In Figure 1, we have given a schematic overview of the AICH reception to be implemented. The combiner receives despread AICH symbols from the RAKE and weighted channel estimates, based on the Common Pilot Channel (CPICH), from the digital signal processor (DSP). The output of the combiner is an estimate of the sent AICH symbol. Up until now, the procedure is identical to what would have been done for a dedicated channel. The purpose of the accumulator block is to multiply a given signature pattern with the received symbols. Each symbol will be weighted, this is to mitigate the influence of the fading over an access slot. The weights are provided from the DSP. The DSP also computes the threshold for detection. The accumulator block compares at the end of an access slot the accumulated symbols with the threshold, and the result is then fed to the DSP. We summarize the AICH detection in the implementation as follows:

1. The accumulator block receives from the DSP which signature pattern to use.
2. Multiply the combiner symbols from the first slot with the corresponding signature pattern symbols, and then add them together. This is done in the first accumulator. Then the remaining 6 symbols from the combiner are multiplied with the

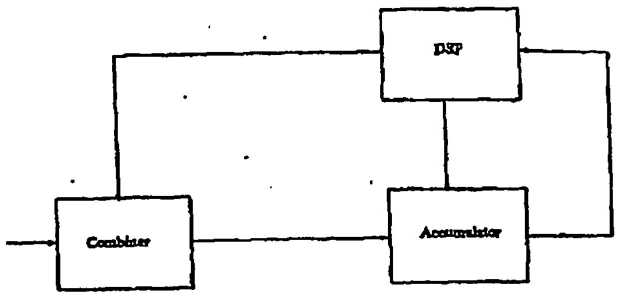

Figure 1: Outline of the different components involved in receiving the AICH.

corresponding signature pattern symbols, added and stored in a second accumulator.

3. Receive two weight factors from the DSP. Multiply the result from the first accumulator with the first weight factor and multiply the result from the second accumulator with the second weight factor, and then add the two numbers. The weight factors are derived from the signal to interference ratio (SIR), calculated for the CPICH.

4. The result is compared to the threshold provided by the DSP, which makes a decision on the acquisition indicator. The decision involves the SIR for the CPICH. The result is then fed back to the DSP.

The reason for using two accumulators is because the fading destroys the orthogonality of the signature patterns if only one accumulator is used.

In Section 2, we describe the algorithm for detecting the AICH signature and in Section 3, we discuss the hardware implementation in more detail and we present performance simulations.

Notation: Let $P(A)$ be the probability for event A. Let x be a random variable. Then $E(x)$ denotes the expectation of the random variable x. Let x^* denote the complex conjugate of x. The Kronecker delta, δ_{ij}, equals 1 if $i = j$ and 0 if $i \neq j$.

2 Algorithm Description for AICH Detection

The sent AICH symbols are given by the complex numbers $b_{s,i} = \pm(1+i)$. The received AICH symbols after despreading are given by

$$y_{i,f}^{(AICH)} = h_{i,f} \sum_{s=0}^{15} \frac{\alpha_s}{\sqrt{2}} AI_s b_{s,i} + n_{i,f}, \tag{1}$$

where the index i enumerates the received symbols and the index f enumerates the multi-path delays or fingers. The radio channel is given by $h_{i,f}$ and α_s^2 denotes the transmitted symbol energy of AICH signature s. The acquisition indicator for signature s is given by AI_s and equals -1, 0, or 1. The interference is modeled by $n_{i,f}$. We have,

$$E(h_{i,f}) = 0, \sum_{f=1}^{F} E(|h_{i,f}|^2) = 1, \tag{2}$$

and

$$\begin{aligned} E(\mathrm{Re}\ h_{i_1,f_1} \mathrm{Re}\ h_{i_2,f_2}) &= 0, f_1 \neq f_2, \\ E(\mathrm{Im}\ h_{i_1,f_1} \mathrm{Im}\ h_{i_2,f_2}) &= 0, f_1 \neq f_2, \\ E(\mathrm{Re}\ h_{i_1,f_1} \mathrm{Im}\ h_{i_2,f_2}) &= 0, f_1 \neq f_2. \end{aligned} \tag{3}$$

Property (3) says that the radio channel multi-paths are independent. For the interference, $n_{i,f}$, we have

$$E(n_{i,f}) = 0, \ E((\mathrm{Re}\ n_{i,f})^2) = E((\mathrm{Im}\ n_{i,f})^2) = \frac{\sigma_f^2}{2}, \tag{4}$$

and

$$E(\mathrm{Re}\ n_{i_1,f_1} \mathrm{Im}\ n_{i_2,f_2}) = 0, \ \forall i_1, f_1, i_2, f_2. \tag{5}$$

For the CPICH the received signal after despreading is given by

$$y_{i,f}^{(CPICH)} = h_{i,f} \frac{\alpha_{CPICH}}{\sqrt{2}} c + n_{i,f} \tag{6}$$

Here, c equals the complex number $1 + i$. We have here made the approximation that the AICH and CPICH interferences are equal. This is reasonable since both transport channels have the same spreading factor. Below, we will need statistics on the interference, which forces us to use the CPICH, since in practice we do not have data samples. In the combiner, we sum over the finge $y_{i,f}^{(AICH)}$ times the complex conjugate of the weighted channel esti

we assume that the CPICH is available for radio channel estimation. Lets assume that over I CPICH symbols the radio channel, $h_{i,f}$, is constant. Let the index j enumerate groups of I symbols. Here, $j = 1, \ldots, J$, where J is the smallest integer such that $J \times I \geq 16$, where the number 16 comes from the fact that there are 16 symbols in an access slot and we therefore need exactly sixteen radio channel estimates. We can then put

$$h_f^{(j)} = h_{i,f}, \; i = 1 + (j-1)I, \ldots, jI. \tag{7}$$

The radio channel estimates can then be computed as,

$$\bar{h}_f^{(j)} = \frac{1}{I} \sum_{i=1+(j-1)I}^{jI} y_{i,f}^{(CPICH)} c^* \approx \sqrt{2}\alpha_{CPICH} h_{i,f} \tag{8}$$

and the interference can be estimated by

$$N_f^{(j)} = \frac{1}{I-1} \sum_{i=1+(j-1)I}^{jI} | y_{i,f}^{(CPICH)} c^* - \bar{h}_f^{(j)} |^2 \approx 2\sigma_f^2. \tag{9}$$

The weighted channel estimates are then given by

$$w_{i,f} = w_f^{(j)} = \frac{\bar{h}_f^{(j)}}{N_f^{(j)}} \approx \frac{\alpha_{CPICH} h_{i,f}}{\sqrt{2}\sigma_f^2}, \; i = 1 + (j-1)I, \ldots, jI. \tag{10}$$

We are here weighting the channel estimates for each finger with its interference, see [4]. If the number of symbols in each block I is small, we could opt for averaging $N_f^{(j)}$ over a couple of blocks before the channel estimates are scaled with its inverse, in order to reduce the uncertainty of the interference estimates.

In what follows, if the index $i > 16$, we define $b_{s,i} = 0$. Let $b_{\hat{s},i}$ be the desired signature sequence. Multiply the derotated symbols with $b_{\hat{s},i}$ and add them together in groups of I symbols, stored in the variable A_j. We have

$$\begin{aligned}
A_j &= \mathrm{Re} \sum_{i=1+(j-1)I}^{jI} b_{\hat{s},i}^* \sum_{f=1}^{F} y_{i,f}^{(AICH)} w_{i,f}^* = \\
&\mathrm{Re}\left(\sum_{f=1}^{F} \alpha_{CPICH} h_f^{(j)} (w_f^{(j)})^*\right) \sum_{s=0}^{15} \frac{\alpha_s}{\sqrt{2}} AI_s \sum_{i=1+(j-1)I}^{jI} b_{s,i} b_{\hat{s},i}^* + \\
&\mathrm{Re} \sum_{f=1}^{F} \sum_{i=1+(j-1)I}^{jI} n_{i,f} (w_f^{(j)})^* b_{\hat{s},i}^*
\end{aligned} \tag{11}$$

Put

$$C_j = \mathrm{Re}\sum_{f=1}^{F} \alpha_{CPICH} h_f^{(j)} (w_f^{(j)})^* \approx \sum_{f=1}^{F} \frac{|\alpha_{CPICH} h_f^{(j)}|^2}{\sqrt{2}\sigma^2}. \qquad (12)$$

Consider

$$\sum_{j=1}^{J} \frac{A_j}{C_j} = \sum_{s=0}^{15} \frac{\alpha_s}{\sqrt{2}} AI_s \sum_{i=1}^{16} b_{s,i} b_{\hat{s},i}^* +$$
$$\mathrm{Re}\sum_{f=1}^{F}\sum_{j=1}^{J} \frac{1}{C_j} \sum_{i=1+(j-1)I}^{jI} n_{i,f} (w_f^{(j)})^* b_{\hat{s},i}^* =$$
$$\frac{32\alpha_{\hat{s}}}{\sqrt{2}} AI_{\hat{s}} + \text{interference}. \qquad (13)$$

The value of $AI_{\hat{s}}$ is now given by (13), assuming the interference is negligible. Essentially, we need to scale the accumulated values A_j with the corresponding CPICH signal to interference ratio, in order to remove the effect of the fading that would otherwise destroy the orthogonality of the signature sequences $b_{s,i}$.

In practice, we need to approximate C_j. This is done using the channel estimates (8), as follows,

$$\hat{C}_j = \mathrm{Re}\sum_{f=1}^{F} \alpha_{CPICH} \bar{h}_f^{(j)} (w_f^{(j)})^* \approx \sum_{f=1}^{F} \frac{|\alpha_{CPICH} h_f^{j}|^2}{\sigma_f^2} \approx SIR^{(CPICH)}. \qquad (14)$$

Here, $SIR^{(CPICH)}$ is the signal to interference ratio for the CPICH. Instead of (13) we then have

$$\sum_{j=1}^{J} \frac{A_j}{\hat{C}_j} = \sum_{s=0}^{15} \frac{\alpha_s}{\sqrt{2}} AI_s \sum_{i=1}^{16} b_{s,i} b_{\hat{s},i}^* +$$
$$\sum_{j=1}^{J} \frac{C_j - \hat{C}_j}{\hat{C}_j} \sum_{s=0}^{15} \frac{\alpha_s}{\sqrt{2}} AI_s \sum_{i=1+(j-1)I}^{jI} b_{s,i} b_{\hat{s},i}^* +$$
$$\mathrm{Re}\sum_{f=1}^{F}\sum_{j=1}^{J} \frac{1}{\hat{C}_j} \sum_{i=1+(j-1)I}^{jI} n_{i,f} (w_f^{(j)})^* b_{\hat{s},i}^* =$$
$$\frac{32\alpha_{\hat{s}}}{\sqrt{2}} AI_{\hat{s}} + \epsilon_1 + \epsilon_2. \qquad (15)$$

Here, ϵ_1 is the error due to the relative error in estimating C_j and ϵ_2 is the interference. Given that the interference is non-negligible, we need to threshold (15) when deciding upon the value of $AI_{\hat{s}}$. Let τ be

the threshold. Then we have

$$AI_i = \begin{cases} -1, & \sum_{j=1}^{J} \frac{A_j}{\hat{C}_j} < -\tau, \\ 1, & \sum_{j=1}^{J} \frac{A_j}{\hat{C}_j} > \tau, \\ 0, & \text{else.} \end{cases} \tag{16}$$

The threshold depends among other things on the probability for false detections (FAR), that is, we detect $AI_i = \pm 1$ when in fact $AI_i = 0$. The FAR is a user specified parameter and the corresponding threshold is denoted τ_{FAR}.

We now compute an analytical expression for τ_{FAR}. Next, we make a number of simplifying assumptions. Assume that the interference term ϵ_2 is normally distributed, and that ϵ_1 is negligible compared to ϵ_2. This is a fairly realistic, assuming we have good channel estimates. Let $n_{i,f}$ be independent of $\hat{C}_j$, $w_f^{(j)}$, and $b_{s,i}$, which is a very benign approximation. The interference is assumed uncorrelated for different symbols, that is,

$$E(\mathrm{Re}\, n_{i_1,f_1} \mathrm{Re}\, n_{i_2,f_2}) = E(\mathrm{Im}\, n_{i_1,f_1} \mathrm{Im}\, n_{i_2,f_2}) = 0, \; i_1 \neq i_2, \; \forall f_1, f_2, \tag{17}$$

which again is very realistic. From (3) it is reasonable to assume

$$E\left(\mathrm{Re}\left(\frac{w_{f_1}^{(j_1)}}{\hat{C}_{j_1}}\right) \mathrm{Re}\left(\frac{w_{f_2}^{(j_2)}}{\hat{C}_{j_2}}\right)\right) = 0, \; f_1 \neq f_2, \; \forall j_1, j_2, \tag{18}$$

and the same for the product of the imaginary parts or the imaginary part times the real part. We get after some lengthy algebra, involving the above independence assumption, (4), (5), (17), (18), and using that for a complex number x

$$\mathrm{Re}\, x = \frac{1}{2}(x + x^*),$$

that

$$E\left(\mathrm{Re}\left(\frac{n_{i_1,f_1} w_{f_1}^{(j_1)} b_{j,i_1}^*}{\hat{C}_{j_1}}\right) \mathrm{Re}\left(\frac{n_{i_2,f_2} w_{f_2}^{(j_2)} b_{j,i_2}^*}{\hat{C}_{j_2}}\right)\right) = 0,$$
$$i_1 \neq i_2 \text{ or } f_1 \neq f_2. \tag{19}$$

Using (10) and (14), we have

$$\sum_{f=1}^{F} E\left(\left(\mathrm{Re} \frac{n_{i,f} w_f^{(j)} b_{j,i}^*}{\hat{C}_j}\right)^2\right) \approx \frac{1}{2STR^{(CPICH)}}. \tag{20}$$

We then have

$$E(\epsilon_2) = 0 \tag{21}$$

and

$$E(\epsilon_2^2) = E\left(\left[\sum_{f=1}^{F}\sum_{j=1}^{J}\sum_{i=1+(j-1)I}^{jI} \mathrm{Re}\frac{n_{i,f}(w_f^{(j)})^* b_{\hat{s},i}^*}{\hat{C}_j}\right]^2\right) =$$
$$\sum_{f_1=1}^{F}\sum_{j_1=1}^{J}\sum_{i_1=1+(j_1-1)I}^{j_1 I}\sum_{f_2=1}^{F}\sum_{j_2=1}^{J}\sum_{i_2=1+(j_2-1)I}^{j_2 I}$$
$$E\left(\mathrm{Re}\left(\frac{n_{i_1,f_1} w_{f_1}^{(j_1)} b_{\hat{s},i_1}^*}{\hat{C}_{j_1}}\right)\mathrm{Re}\left(\frac{n_{i_2,f_2} w_{f_2}^{(j_2)} b_{\hat{s},i_2}^*}{\hat{C}_{j_2}}\right)\right) \approx 8ISR^{(CPICH)} \tag{22}$$

The approximation follows from (19) and (20). Here, $ISR^{(CPICH)}$ denotes the average interference to signal ratio. We can therefore estimate $E(\epsilon_2^2)$ by filtering

$$ISR_j^{(CPICH)} = \sum_{f=1}^{F}\frac{N_f^{(j)}}{|h_f^{(j)}|^2}. \tag{23}$$

That is, for some filter parameter λ_{ISR},

$$ISR_{filt,j}^{(CPICH)} = (1-\lambda_{ISR})ISR_{filt,j-1}^{(CPICH)} + \lambda_{ISR} ISR_j^{(CPICH)}. \tag{24}$$

Then

$$ISR^{(CPICH)} \approx ISR_{filt,j}^{(CPICH)}.$$

If none of the sent signatures matches $\hat{s}$, we have that in (15)

$$\sum_{j=1}^{J}\frac{A_j}{\hat{C}_j} = \epsilon_2, \tag{25}$$

assuming that ϵ_1 is negligible. We would like to bound the false detection rate (FAR), that is, we need to find l_{FAR} such that

$$P(|\sum_{j=1}^{J} C\frac{A_j}{\hat{C}_j}| > Cl_{FAR}\sigma_{\epsilon_2}) = FAR. \tag{26}$$

Here, C is a variable whose only purpose is to make the quotients $C/\hat{C}$ close to one. This is to facilitate the hardware implementation of the algorithm. In general FAR equals 0.1, 0.03, 0.01. Substituting (25) into (26), we get

$$P(|\epsilon_2| > l_{FAR}\sigma_{\epsilon_2}) = FAR. \tag{27}$$

FAR	l_{FAR}
0.1	1.6
0.03	2.2
0.01	2.6

Table 1: The l_{FAR} values assuming that $\epsilon_1 = 0$ and ϵ_2 is normally distributed.

Here ϵ_2 is assumed to be normally distributed. From tables of normal distributions, we get the l_{FAR} values, which can be seen in Table 1. From simulations it will be shown that the analytical l_{FAR} values agrees quite close to the simulated values. The above computations can be summarized in the following algorithm:

Algorithm

(i) Choose the integer I that approximates the radio channel as static over I symbols, each with spreading factor 256. Choose the false detection rate factor l_{FAR} and the signature sequence $\hat{s}$. The access slot will consist of J symbol blocks, each containing I symbols. Choose the filtering parameter λ_{ISR}.

(ii) Compute

$$A_j = \mathrm{Re} \sum_{i=1+(j-1)I}^{jI} b_{\hat{s},i}^{*} \sum_{f=1}^{F} y_{i,f}^{(AICH)} w_{i,f}^{*}.$$

Here, $b_{\hat{s},i}$ is the ith symbol in the signature sequence $\hat{s}$, $y_{i,f}^{(AICH)}$ is the received AICH signal after despreading for multi-path f, and $w_{i,f}$ is the weighted radio channel estimate for symbol i and multi-path delay f.

(iii) Compute

$$\hat{C}_j = \mathrm{Re} \sum_{f=1}^{F} \alpha_{CPICH} \bar{h}_f^{(j)} (w_f^{(j)})^{*}.$$

Here, $\bar{h}_f^{(j)}$ is the radio channel estimate for symbol group j and multi-path delay f.

(iv) Compute

$$\sum_{j=1}^{J} C \frac{A_j}{\hat{C}_j}.$$

Here, C is a variable to make the division $C/\hat{C}_j$ more tractable. For example,

$$C = \max\{\hat{C}_1, \ldots, \hat{C}_J\}.$$

(v) Compute the interference to signal ratio for the CPICH for symbol group J, that is,

$$ISR_j^{(CPICH)} = \sum_{f=1}^{F} \frac{N_f^{(j)}}{|\hat{h}_f^{(j)}|^2}.$$

Here, $N_f^{(j)}$ estimates the interference for symbol block j and multipath delay f. Compute the filtered values as

$$ISR_{filt,j}^{(CPICH)} = (1 - \lambda_{ISR}) ISR_{filt,j-1}^{(CPICH)} + \lambda_{ISR} ISR_j^{(CPICH)}.$$

(vi) Take

$$\sigma_{e_2} = \sqrt{8 ISR_{filt,J}^{(CPICH)}}.$$

and

$$\tau_{FAR} = Cl_{FAR}\sigma_{e_2}.$$

The acquisition indicator is then given by

$$AI_s = \begin{cases} -1, & \sum_{j=1}^{J} C\frac{A_j}{\hat{C}_j} < -\tau_{FAR}, \\ 1, & \sum_{j=1}^{J} C\frac{A_j}{\hat{C}_j} > \tau_{FAR}, \\ 0, & \text{else.} \end{cases}$$

3 Implementation and Simulations

In the implementation we chose $J = 2$, that is, the first group consists of 10 symbols and the second group of 6 symbols. We then computed

$$C\frac{A_1}{\hat{C}_1} + C\frac{A_2}{\hat{C}_2} = C\sum_{s=0}^{15} \frac{\alpha_s}{\sqrt{2}} AI_s \sum_{i=1}^{16} b_{s,i} b_{\hat{s},i}^* + \tag{28}$$

$$C\frac{\hat{C}_1 - \hat{C}_1}{\hat{C}_1} \sum_{s=0}^{15} \frac{\alpha_s}{\sqrt{2}} AI_s \sum_{i=1}^{10} b_{s,i} b_{\hat{s},i}^* + \tag{29}$$

$$C\frac{C_2 - \hat{C}_2}{\hat{C}_2}\sum_{s=0}^{15}\frac{\alpha_s}{\sqrt{2}}AI_s\sum_{i=11}^{16} b_{s,i}b^*_{\hat{s},i} + \qquad (30)$$

$$\mathrm{Re}\sum_{f=1}^{F}\sum_{j=1}^{J}\frac{C}{\hat{C}_j}\sum_{i=1+(j-1)I}^{jI} n_{i,f}(w_f^{(j)})^* b^*_{\hat{s},i} \qquad (31)$$

We chose

$$C = \max\{\hat{C}_1, \hat{C}_2\}.$$

Let the signature $\hat{s}$ not be among the transmitted ones. Term (28) is then zero. If (29) and (30) do not cancel, that is, ϵ_1 in Section 2 is not negligible, the FAR will depend on the magnitude of

$$\tilde{\Delta}_{s,\hat{s}} = \mathrm{Re}\sum_{s=0}^{15}\frac{\alpha_s}{\sqrt{2}}AI_s\sum_{i=11}^{16} b_{s,i}b^*_{\hat{s},i} \qquad (32)$$

as well on σ_{ϵ_2}, which is the standard deviation of term (31).

In the simulations, we set the CPICH to -10 dB, the Primary Control Physical Channel (P-CCPCH) is set to -12 dB, the Synchronization Channel (SCH) is set to -12 dB, and the remaining energy is transmitted as Orthogonal Channel Noise (OCN). The total transmit power from the CPICH, P-CCPCH, SCH, OCN, and one AICH user is set to one. An energy of -10 dB corresponds then to an energy of 0.1. Any additional AICH signatures will increase the total transmit power to above one. All AICH signature symbol energies, α_s^2, are set to the same value, given by

$$AICH_{offset} + 20\log\alpha_{CPICH}\ \mathrm{dB}.$$

In the simulations, we added additive white Gaussian noise with variance $10^{\pm 0.6}$ to each chip. In the tables, we refer to this as ± 6 dB noise.

When all signature energies are equal, we have that $\tilde{\Delta}_{s,\hat{s}}$ can be written as

$$\tilde{\Delta}_{s,\hat{s}} = \frac{\alpha}{\sqrt{2}}\mathrm{Re}\sum_{s=0}^{15}AI_s\sum_{i=11}^{16} b_{s,i}b^*_{\hat{s},i} = \frac{\alpha}{\sqrt{2}}\Delta_{s,\hat{s}}. \qquad (33)$$

In Appendix A, we show that the range of $\Delta_{s,\hat{s}}$ is between -18 and 18.

In Table 2, we show the dependence of l_{FAR} for different signature energies, $\Delta_{s,\hat{s}}$, and radio channel noise. In order to test the AICH detection under the worst possible conditions, we used a radio channel that employed rapid fading (120 km/h), and multi-path locations determined by case 3 in [2]. As is expected, l_{FAR} depends on $\Delta_{s,\hat{s}}$, but not significantly on the noise level N_0. The dependence on the

signature energies is negligible, unless $\Delta_{s,t}$ is high. In reality the allocated signature sequences changes randomly from one access slot to the other, which implies that the worst case scenario of having $\Delta_{s,t} = 18$ in one access slot will most likely not be the case in the next access slot. In essence, for most signature sequence combinations l_{FAR} is relatively stable. From the table, we chose the following l_{FAR} values; $l_{0.1} = 1.6$, $l_{0.03} = 2.3$, and $l_{0.01} = 2.8$. It should be observed that these values are quite close to the theoretical values in Table 1.

In Table 3, we present performance results for an additive white Gaussian noise channel, where the chip noise is set to -1 dB. We have $AI_0 = 1$, and $AI_s = 0$, $s = 1, \dots, 15$. The $MISS$ column indicates the probability for missing the detection of $AI_0 = 1$ and the FAR column is the average probability for a false detection for signature 1 to 15. The l_{FAR} values have been chosen from the results of Table 2. The table is part of the performance requirements in the 3GPP specification, where for a target FAR of 0.01, we must have $MISS$ less than 0.01 and estimated FAR less than 0.01 for an $AICH_{offset}$ of -12 dB. This is clearly achievable by the algorithm, however, with a small margin. The same performance chart is presented in Table 4, with the only difference that the radio channel's multi-path delays and speed is given by case 3, and the chip noise is -6 dB.

Conclusions

We have derived a scheme for AICH detection that accumulates the received signature symbols in blocks, where the blocks are weighted before being summed. A threshold for determining the acquisition indicator sign was derived, based on the signal to interference ratio of the CPICH. Simulations confirmed that the algorithm proves viable in practice.

3.1 ClearCase Label and Files

The simulations are based on the ClearCase label

IMT2000_SIM_FUNCTIONAL_ECSXIAO_DL_WILGOT_010504.

Changes and additions have been made to the label and are stored under the label

ECSLEEE_AICH_ASIC_1.

The following COSSAP-models need to be imported

/vobs/imt2000/d/ms/rx/c/aich_acum,

$\Delta_{s,\hat{s}}$	0		6		18	
N_0	-6 dB	6 dB	-6 dB	6 dB	-6 dB	6 dB
$AICH_{offset}$						
			$FAR = 0.1$			
-14 dB	1.6	1.5	1.7	1.6	1.9	1.8
-10 dB	1.6	1.5	1.7	1.6	2.0	2.0
-6 dB	1.6	1.5	1.7	1.7	2.4	2.6
			$FAR = 0.03$			
-14 dB	2.3	2.1	2.4	2.1	2.6	2.5
-10 dB	2.3	2.1	2.4	2.3	2.8	2.9
-6 dB	2.3	2.1	2.4	2.4	3.3	3.6
			$FAR = 0.01$			
-14 dB	2.8	2.6	2.8	2.6	3.0	3.0
-10 dB	2.8	2.6	2.9	2.9	3.4	3.5
-6 dB	2.8	2.6	3.0	3.2	4.0	4.3

Table 2: The $AICH_{offset}$ ranges from -14 dB to -6 dB, $\Delta_{s,\hat{s}}$ is set to 0, 6, or 18, and the signal to noise ratio, N_0, is set to -6 dB or 6 dB. The l_{FAR} values are shown for a user equipment traveling at 120 km/h.

$AICH_{offset}$	FAR, $l_{0.1} = 1.6$	$MISS$
-14	0.1072	0.0015
-12	0.1079	0
-10	0.1082	0
	FAR, $l_{0.03} = 2.3$	$MISS$
-14	0.0213	0.0124
-12	0.0209	0.0001
-10	0.0215	0
	FAR, $l_{0.01} = 2.8$	$MISS$
-14	0.0049	0.0366
-12	0.0050	0.0010
-10	0.0052	0

Table 3: The signature of interest is $\hat{s} = 0$. We have $AI_0 = 1$ and $AI_s = 0$, $s = 1, \ldots, 15$. The radio channel is an additive white Gaussian noise channel with a signal to noise ratio of -1 dB.

$AICH_{offset}$	FAR, $l_{0.01} = 1.6$	$MISS$
-14	0.1112	0.2675
-10	0.1116	0.0470
-6	0.1136	0.0020
	FAR, $l_{0.03} = 2.3$	$MISS$
-14	0.0289	0.5260
-10	0.0295	0.1341
-6	0.0307	0.0076
	FAR, $l_{0.01} = 2.8$	$MISS$
-14	0.0106	0.7120
-10	0.0106	0.2516
-6	0.0113	0.0178

Table 4: The signature of interest is $\hat{s} = 0$. We have $AI_0 = 1$ and $AI_s = 0$, $s = 1, \ldots, 15$. The radio channel models the user equipment traveling at 120 km/h with a signal to noise ratio of -6 dB.

/vobs/imt2000/d/ms/rx/c/i_weight_fix_aich,
/vobs/imt2000/d/bs/tx/c/add_aich,
/vobs/imt2000/d/bs/tx/c/add_aich4,
/vobs/imt2000/d/bs/tx/c/aich_gen_tx.

The following hierarchical COSSAP-models need to be imported

/vobs/imt2000/d/bs/tx/h/bs_aich_tx,
/vobs/imt2000/d/ms/rx/h/dsp_fix_aich,
/vobs/imt2000/d/ms/rx/h/combiner_aich.

The simulation test bench schematic and assignment file are stored as

/vobs/imt2000/c/schematic/aich_tx.sch,
/vobs/imt2000/c/Wilgot/aich.asn,

and a MATLAB script to analyze the output can be found in

/vobs/imt2000/matlab/aich.m.

The MATLAB script was used to create the table entries. For test vector generation, we used the schematic and assignment file

/vobs/imt2000/c/schematic/aich_test_vec.sch,
/vobs/imt2000/c/Wilgot/aich_test_vec.asn.

3.2 AICH Detection COSSAP Model and Bit widths

The file

/vobs/imt2000/d/ms/rx/c/aich_acum

does the the AICH detection. The following parameters need to be set in the COSSAP-model

Fix_mode If one, we use fix-point approximations.

Threshold This is l_{FAR} as defined above.

Signature The signature sequence to be detected, which is a number between 0 and 15.

Testvector If one, test vectors are created.

Lambda This is λ_{IRS} as defined above. In the implementation this parameter is set to 1/16.

Binary_digits_SIR_quotient The number of binary digits to use when computing $C/\hat{C}_j$ as defined above. In the implementation it is 3, that is, we approximate

$$\frac{C}{\hat{C}_j} \approx a_{-1}2^{-1} + a_{-2}2^{-2} + a_{-3}2^{-3},$$

where $a_i = 0, 1$.

Binary_digits_weight Number of binary digits to use for the approximation of $C/\hat{C}_j$, computed previously, times a factor 2^{-q}. Here, we took the variable to be 11, that is, in the hardware we represent

$$2^{-q}\frac{C}{\hat{C}_j} \approx a_0 2^0 + a_{-1}2^{-1} + \ldots + a_{-11}2^{-11}.$$

The integer q comes from scaling the weighted channel estimates with a factor 2^{q+4} before sending them to the combiner. This is done once per slot. We need to remove the scaling, up to a constant factor 2^4, before the symbols from the accumulators can be compared. Fore more information regarding the scaling, see [3].

Binary_digits_inv_SIR The $SIR^{(CPICH)}$ is computed once a slot. In our algorithm, we need the inverse $ISR^{(CPICH)}$ for the thresholding. We here specify the number of binary digits used when inverting $SIR^{(CPICH)}$, that is,

$$ISR^{(CPICH)} \approx a_0 2^0 + a_{-1}2^{-1} + \ldots + a_{-9}2^{-9}.$$

We are here using 9 binary digits.

RAKE_offset_diff The difference between the offsets for the AICH and CPICH in the RAKE. We need to compensate for this in the threshold. This parameter was set to 1, because the RAKE offset was set to 4 for the AICH and to 3 for the CPICH.

The threshold in the presence of no Tx-diversity is then given by

$$16 l_{FAR}\sqrt{8ISR^{(CPICH)}}\max\{\hat{C}_1, \hat{C}_2\}2^{-\text{RAKE\_offset\_diff}}$$

and in the presence of Tx-diversity

$$16 l_{FAR}\sqrt{16ISR^{(CPICH)}}\max\{\hat{C}_1, \hat{C}_2\}2^{-\text{RAKE\_offset\_diff}}.$$

The discrepancy is the result of how the channel estimates are scaled.

3.3 Test Vectors

The test-vectors were generated using the Webrunner for a number of different cases. The relevant job numbers are xxx, xxy, which contain further information about specific parameter settings.

A A Worst Case Signature Sequence Combination

In this appendix, we investigate the cross-correlation properties of the signatures. Let the signature energies α_s^2 be bounded by α_{MAX}^2. We would like to know what combination of AI_s and α_s maximizes $|\tilde{\Delta}_{s,\tilde{s}}|$. Define the inner products

$$\beta_{s,\tilde{s}} = \mathrm{Re}\sum_{i=11}^{16} b_{s,i} b_{\tilde{s},i}^*, \; s, \tilde{s} = 0, \ldots, 15.$$

Given $\tilde{s}$, we have always 3 inner products that equals 2, 3 inner products that equals -2, and 1 inner products that equals -6. For some subset, called $s_1, \ldots, s_7$, of the set $0, \ldots, 15$, we have

$$\tilde{\Delta}_{s,\tilde{s}} = 2(\alpha_{s_1}AI_{s_1} + \alpha_{s_2}AI_{s_2} + \alpha_{s_3}AI_{s_3}) - 2(\alpha_{s_4}AI_{s_4} + \alpha_{s_5}AI_{s_5} + \alpha_{s_6}AI_{s_6}) - 6\alpha_{s_7}AI_{s_7}.$$

It is now immediate that $|\ \bar{\Delta}_{s,\dot{s}}\ |$ becomes maximized if we pick, for example,

$$AI_{s_1} = AI_{s_2} = AI_{s_3} = 1,$$
$$AI_{s_4} = AI_{s_5} = AI_{s_6} = AI_{s_7} = -1,$$

and all signal energies equal to α_{MAX}. We then get

$$\bar{\Delta}_{s,\dot{s}} = 18\alpha_{MAX}.$$

Patent Claims:

1. A method of detecting an acquisition signal, comprising the steps of:
- receiving a first signal comprising an access slot comprising a first slot part and a second slot part, each slot part comprising a number of signal symbols,
- obtaining a signature pattern comprising a first signature part and a second signature part, each signature part comprising a number of signature symbols,
- multiplying each signal symbol of said first slot with corresponding signature symbols of said first signature part and deriving a first sum of the products of multiplication,
- multiplying each signal symbol of said second slot with corresponding signature symbols of said second signature part and deriving a second sum of the products of multiplication,
- obtaining a first and a second weight factor, and
- adding said first sum multiplied by said first weight factor and said second sum multiplied by said second weight factor giving a first result, and
- comparing said first result and a detection threshold in order to determine whether an acquisition signal is detected or not.

2. A method according to claim 1, characterized in that said detection threshold is derived based on a signal to interference ratio of a common pilot channel (CPICH).

3. A method according to claims 1 - 2, characterized in that said method further comprises a step of deriving said detection threshold.

4. A method according to claims 1 – 3, characterized in that said first and second weight factors are derived on the basis of a signal to interference ratio (SIR) calculated for a common pilot channel (CPICH).

5. A method according to claims 1 - 4, characterized in that said first signal is selected from the group of:

- an AICH signal, and
- another type of signal.

6. A method according to claims 1 – 5, characterized in that said first signal is an estimated signal derived on the basis of weighted channel estimates, based on a common pilot channel (CPICH), and of de-spread symbols from a RAKE.

7. A method of detection an acquisition signal, where said method comprises accumulation of received signature symbols in groups/blocks, the groups/blocks being weighted before being summed, deriving a indication threshold used for determining an acquisition indicator, said threshold being dependent on a signal to interference ratio of a common pilot channel (CPICH).

8. A device for detecting an acquisition signal, said device comprising:
- means for receiving a first signal comprising an access slot comprising a first slot part and a second slot part, each slot part comprising a number of signal symbols,
- means for obtaining a signature pattern comprising a first signature part and a second signature part, each signature part comprising a number of signature symbols,
- means for multiplying each signal symbol of said first slot with corresponding signature symbols of said first signature part and deriving a first sum of the products of multiplication,
- means for multiplying each signal symbol of said second slot with corresponding signature symbols of said second signature part and deriving a second sum of the products of multiplication,
- means for obtaining a first and a second weight factor, and
- means for adding said first sum multiplied by said first weight factor and said second sum multiplied by said second weight factor giving a first result, and
- means for comparing said first result and a detection threshold in order to determine whether an acquisition signal is detected or not.

9. A device for detection an acquisition signal, said device comprising means for accumulation of received signature symbols in groups/blocks, means for weighting the groups/blocks before being summed, means for deriving a indication threshold used for determining an acquisition indicator, said threshold being dependent on a signal to interference ratio of a common pilot channel (CPICH).

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FIGURE 2

Table 22: AICH signature patterns

s	$b_{s,0}, b_{s,1}, \dots, b_{s,31}$																															
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1
2	1	1	1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1
3	1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1
4	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1
5	1	1	-1	-1	1	1	-1	-1	-1	-1	1	1	-1	-1	1	1	1	1	-1	-1	1	1	-1	-1	-1	-1	1	1	-1	-1	1	1
6	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1
7	1	1	-1	-1	-1	-1	1	1	-1	-1	1	1	1	1	-1	-1	1	1	-1	-1	-1	-1	1	1	-1	-1	1	1	1	1	-1	-1
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
9	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1
10	1	1	1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1	1	1
11	1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	-1	-1
12	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1
13	1	1	-1	-1	1	1	-1	-1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	1	1	-1	-1	1	1	-1	-1
14	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	-1	-1	-1	-1
15	1	1	-1	-1	-1	-1	1	1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	1	1	-1	-1	-1	-1	1	1

5.3.3.8 CPCH Access Preamble Acquisition Indicator Channel (AP-AICH)

The Access Preamble Acquisition Indicator channel (AP-AICH) is a fixed rate (SF=256) physical channel used to carry AP acquisition indicators (API) of CPCH. AP acquisition indicator API_s corresponds to AP signature s transmitted by